A Novel VNIR/SWIR Imaging Spectrometer Form for Size, Weight, and Power Limited Applications

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Background

Current imaging spectrometer forms for terrestrial remote sensing in the visible, near and shortwave infrared (VNR/SWIR) spectral range have been implemented in hardware and achieve a high level of performance in terms of both aberration control and signal to noise level. These forms are compact, relative to prior art, but more size, weight and power (SWaP) optimization, while maintaining performance, is desirable for usage on small satellite platforms. Pursuant of that goal, we have developed a compact breadboard prototype VNIR/SWIR imaging spectrometer that maintains the current aberration control and has a large number of spatial samples. The new form utilizes a catadioptric lens and a flat dual-blaze immersion grating yielding a compact design that is relatively easy to manufacture.

Chrisp Compact VNIR/SWIR Imaging Spectrometer (CCVIS)

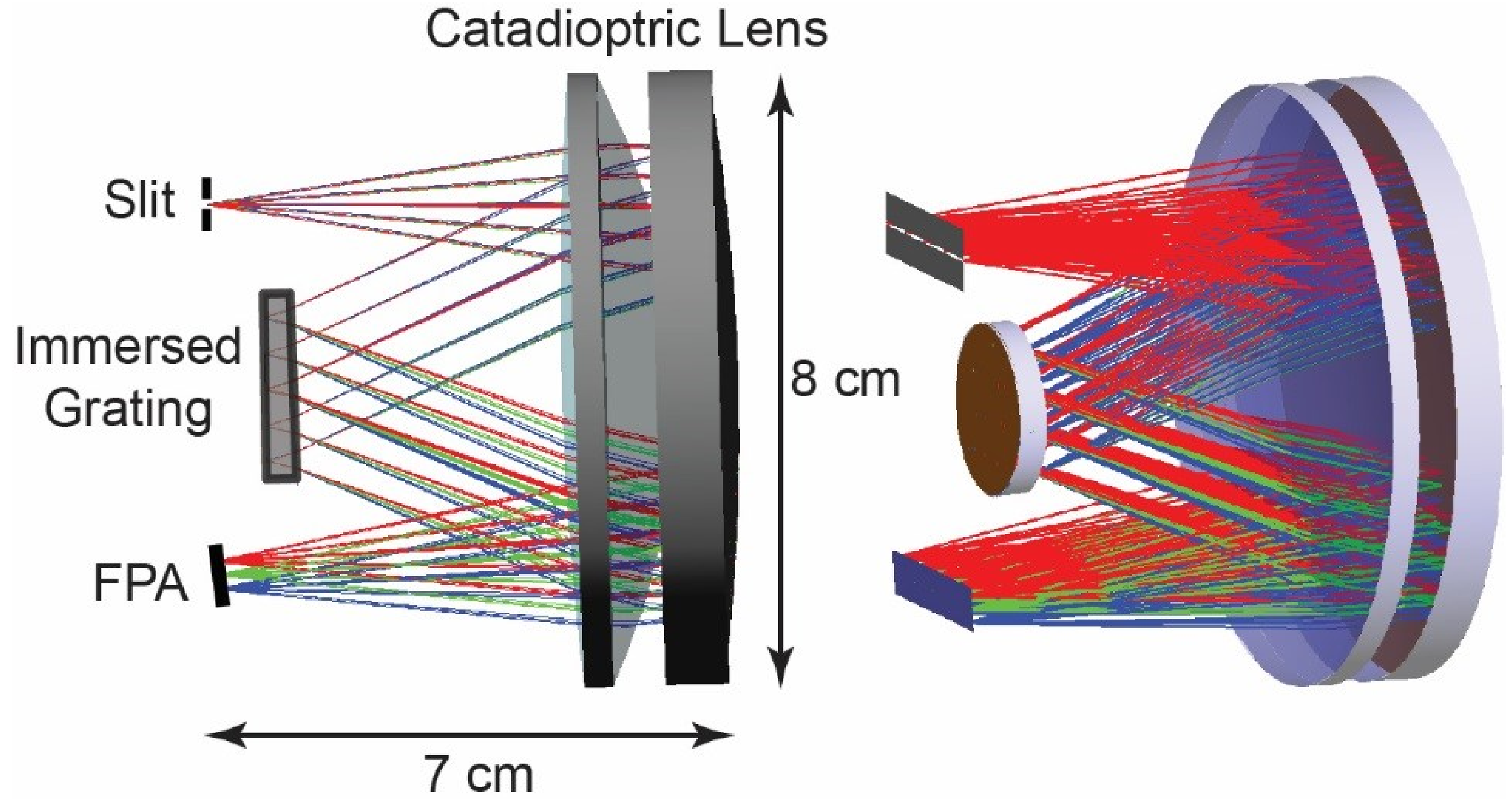


Figure 1: CCVIS design

Figure 1 is the CCVIS form comprised of a slit, a catadioptric lens, an immersed grating, and a focal plane array (FPA). The key attributes are the small volume (352 cm^3), the simplicity that facilitates manufacturing and alignment, and the flat immersed grating, that also has manufacturing advantages. In addition to reducing the size and weight, it is expected that the small volume will aid in thermal control, without extensive packaging, providing a stable radiometric and spectral calibration. The optical form only supports a single FPA necessitating the use of a substrate-removed MCT array.

The fabrication of the dual-blaze grating is considerably simplified in comparison to the powered grating employed in other designs (Figure 2). We have developed a gray-scale photolithographic manufacturing technique that doesn't require any stitching. One great advantage of this approach is that once the process is perfected then grating production is rapid and robust. The air slit is also manufactured using microfabrication processes, in this case using photolithography and a Bosch deep silicon etch process.

Comparison to the State of the Art

Figure 2 illustrates two state-of-the-art imaging spectrometer forms developed at JPL and the CCVIS, drawn to scale. One is an Offner-Chrisp designed for the HyspIRI mission and the second is the CWIS Dyson design*. Both high performance design forms have been demonstrated in hardware. Note that both utilize powered gratings. All three forms have 1600 spatial samples and better than 90% uniformity. Table 1 is a comparison of the three imaging spectrometers.

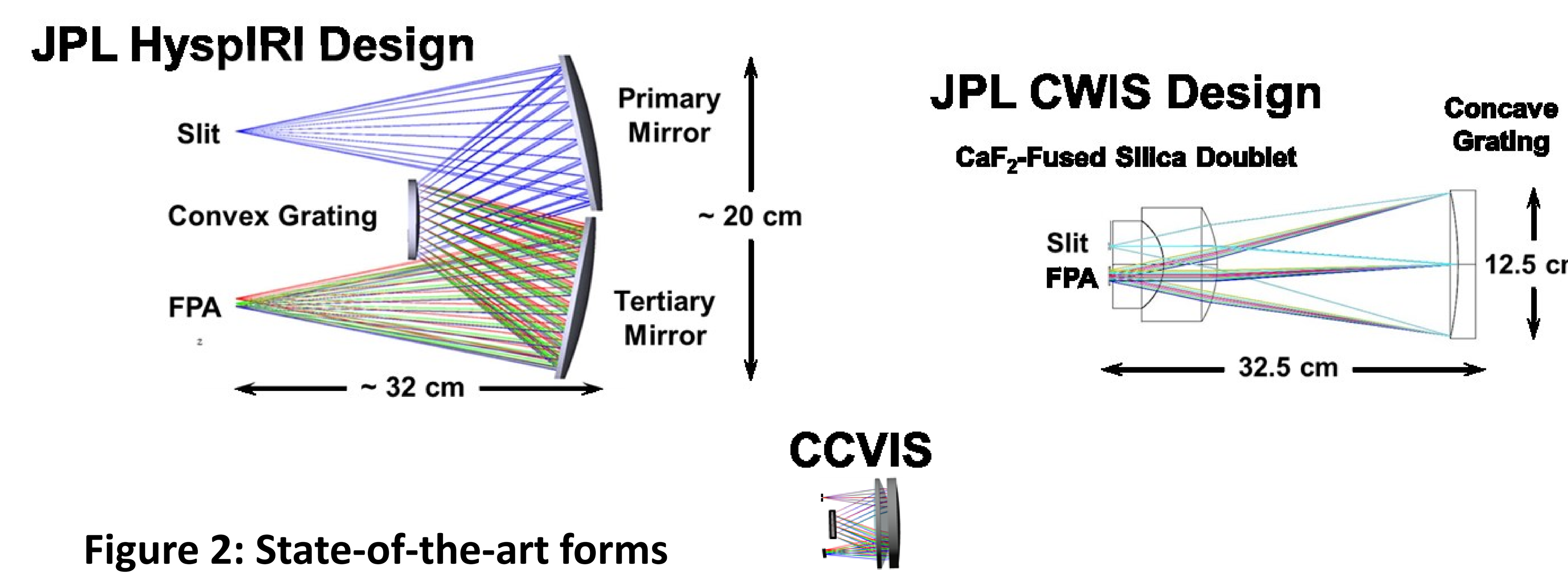
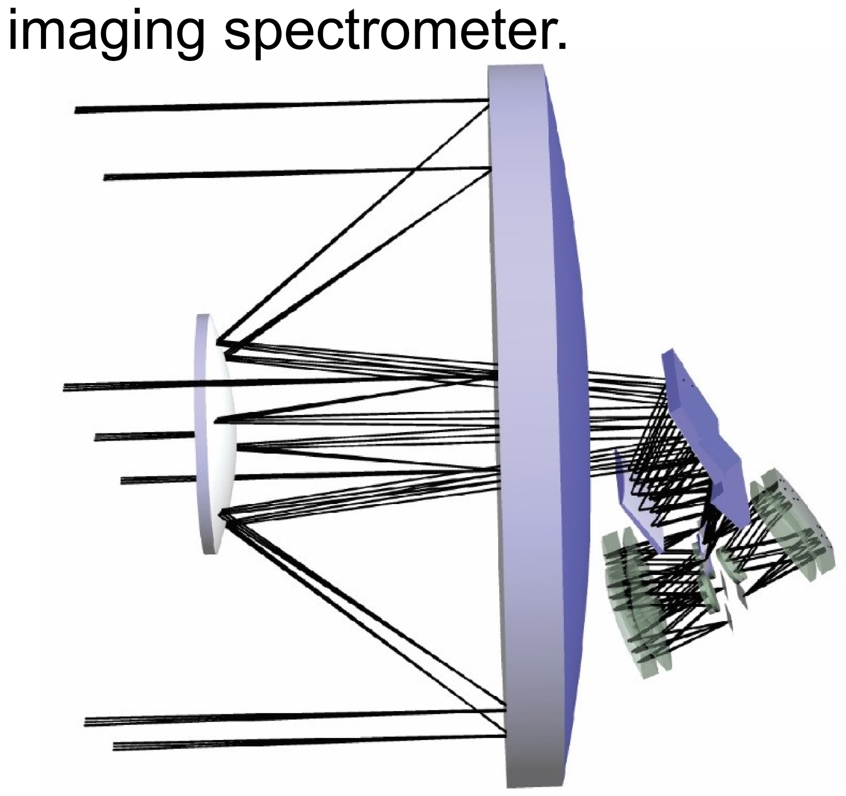


Figure 2: State-of-the-art forms

	Offner-Chrisp	Dyson	CCVIS
Spectral range (nm)	380-2500		400-2500
Optics	All reflective	Reflective & refractive	
F-number	2.8	1.8	2.3
Dual-blaze grating	Convex	Concave	Flat
Volume (cm^3)	~6400	3988	352

Table 1: Optical property comparison

Figure 3 illustrates using three CCVIS spectrometers, a conventional Ritchey-Chrétien telescope, and a free form corrector to produce a space-based, wide field imaging spectrometer.



Wide Field Design Parameters	
Entrance pupil	80 cm diameter
F-number	3.75
Altitude	400 km
3 spectrometer swath	19 km
Spectral interval	8 nm
FPA	1600 × 240 pixels
Pixel size	30 microns
Ground sample distance	4 m

Figure 3: Wide-field imaging spectrometer concept

*H. A. Bender et al, "Wide-field imaging spectrometer for the Hyperspectral Infrared Imager (HyspIRI) mission," (SPIE, 2014), vol. 9222 of Proceedings of SPIE, pp. 92220E1-8.
B. V. Gorp et al, "Design of the Compact Wide Swath Imaging Spectrometer (CWIS)," (SPIE, 2014), vol. 9222 of Proceedings of SPIE, pp. 92220C1-9.